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The Application of Membrane Bioreactor for Greywater Treatment

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ABSTRACT

Urban planning management should consider wastewater as a challenge. Wastewater, in this case, grey water, is full of dangerous contaminants and, at specific concentrations, can turn into a substance that affects the environment. The effluent of the released waste must therefore be managed to ensure that it complies with the government's quality standard criteria. The membrane bioreactor (MBR) technology process produced waste effluents with low concentrations of biological oxygen demand (BOD_5), chemical oxygen demand (COD), and total organic carbon (TOC), proving its higher efficiency as a biological processing stage. Total *coliforms* and *E. coli* are not present in processed products, detergents and total suspended solid (TSS) are effectively degraded. This is made possible by the considerably lower organic load; as a result, biomass accumulation slows and mixed liquor suspended solids (MLSS), which have low value, are produced. With the assistance of continuous airflow, and without the use of chemicals or backwashing, an ultrafiltration module (UF) with a membrane cut-off size small enough to be able to create a constant permeate flux during the grey water treatment process is necessary. Although processed grey water does not pass denitrification, all parameters linked to the quality of the effluent water exceed environmental quality criteria.

Keywords: membrane bioreactor, wastewater, greywater, BOD, COD, total *coliform.*

INTRODUCTION

In this study, wastewater, namely grey water, is one of the environmental health factors that must be considered to prevent disease(Asan et al., 2020). Wastewater from sinks, drainage pipes, and kitchens and bathroom sinks is referred to as grey water (Liberman et al., 2016). This grey water typically comprises fat and even feces in the form of food waste from the kitchen, whereas kitchen trash contains a lot of detergents (Bodzek et al., 2019). This grey water contains a significant number of hazardous pollutants, which, at a certain concentration, can transform into substances that are potentially harmful to the environment and even to human health. Therefore, the effluent from this grey water that is released must be managed to ensure that it complies with the government-set standards for quality.

There are numerous alternative greywater treatment technologies in use today that work to reduce the volume, parameter concentration, and toxicity of waste as risk factors for environmental pollution (Chang et al., 2002; Hernaningsih, 2018). However, to achieve an effective and efficient concentration reduction performance, it is necessary to determine how suitable technology is applied to grey water (Gürel and Büyükgüngör, 2015; Liberman et al., 2016). Adding a recycling processing facility usually requires a sizable quantity of space, yet there is typically relatively limited land available in urban areas(Banaszak et al., 1998; Rodrigues et al., 2023). The use of the Membrane Bioreactor system is one of the technologies that might be developed for this purpose. The wastewater treatment technology known as MBR has been used extensively around the world (Mohd Azoddein et al., 2015). As the community's demands change, so does the development of its use (Aditia, 2020). The capacity for wastewater treatment can also be modified to meet current demands; for instance, it can be increased to 5,000 or 10,000 l/hour (Huang et al., 2020).

An activated sludge method that is also fitted with a Membrane Bioreactor (MBR) System was tested to overcome the shortcomings of the conventional system (i.e., the activated sludge method) (Gede Wenten et al., 2020; Osman, 2014). Except for the separation of activated sludge and effluent, which is accomplished using a filtration membrane as a substitute for the sedimentation phase, the MBR concept is technically identical to conventional biological waste treatment (Gede Wenten et al., 2020). This system's utilization may process organic or inorganic substances with high concentrations and variable loads while also improving the effluent's quality (Gupta, 2018). Due to the system's weaknesses in terms of cost and the requirement for reliable and skilled human resources during maintenance, it is still not widely used in Indonesia (Al-Khafaji et al., 2022; Gede Wenten et al., 2020; Nandari et al., 2018). There is one more benefit to this arrangement, though, and that is the requirement for less space (because it does not require a clarifier as a settling basin) (Fernando, 2019). This will consider the limited nature of land and water resources (Chang et al., 2002; Huang et al., 2020; Judd, 2005).

Additionally, this technique is significantly more sophisticated than conventional treatment methods, which are unable to handle wastewater with continuously variable water discharge. MBR can help improve the quality of domestic wastewater, such as grey water, which is typically treated using more conventional methods despite having lower quality (Banaszak et al., 1998; Liberman et al., 2016). The use of MBR is increasing even though the investment and operating expenses with this MBR performance are higher than those of conventional processing technology (Banaszak et al., 1998; Le-Clech et al., 2006). This is because the effluent from recycling grey water is of such high quality that it may be utilized to supplement increasingly scarce pure water sources. This study will discuss about how grey water treatment plants, which use the membrane bioreactor (MBR) system to clean the water and turn it into clean water, can be used. Also, to assess the effectiveness of the outputs of the wastewater treatment process utilizing the Membrane Bioreactor System (MBR) that comes from the Wastewater Treatment Plant (WWTP).

MATERIALS AND METHODS

MBR definition and classification

This study uses a research and development method with an experimental approach. The research and development is carried out using membrane bioreactor (MBR) wastewater treatment technology. The experimental process, testing the MBR in gray water to remove wastewater parameters. The chemical parameters are (BOD_5, COD, TOC, NH_3, NO_3, NO_2, and detergents) and biological pollutants (total *coliform* and *Escherichia coli*) in greywater. MBR technology for treating wastewater has become an issue all over the world (Aditia, 2020; Liberman et al., 2016). This technology is the result of combining activated sludge with extra filtering membranes to separate biomass from waste in conventional processes (Ladewig and Al-Shaeli, 2017). Compared to the conventional activated sludge process, MBR can produce much higher quality effluent because it gets rid of all suspended solids, colloidal solids, and bacteria that have trapped to surfaces (Inc et al., 2013). Membrane bioreactors can be run with high MLSS concentrations so they can treat more wastewater at once (Liao et al., 2018).

MBR is a technology that uses pressure on the filtration membrane in place of gravity-based purification (used to remove active biomass from liquid mixtures) to naturally increase the efficiency of conventional wastewater treatment membrane processes (Bodzek et al., 2019; Chu et al., 2014; Huang et al., 2020). The fundamental ideas are still the same as in conventional systems and are based on the idea that pollutants can be reduced through biological reactions. In principle, MBR is a system for treating wastewater that uses a membrane that is either outside or submerged in a bioreactor (Chang et al., 2002). A combination of membranes is used inside the bioreactor for the biomass separation process. In this case, membranes also take the place of sedimentation ponds, which were used before to separate solids from liquids (Hernaningsih, 2018).

The method for separating water and solids heavily relies on the usage of membranes. In general, there are three types of membranes: anisotropic membranes, membranes formed of ceramics, metals, and liquid film layers, as well as isotropic membranes (microporous membranes, non-porous or non-porous dense membranes, and electrically charged membranes). Microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), reverse osmosis (RO), electrodialysis (ED), and electro de-ionization (EDI) are all common separation procedures; the first four processes produce permeate (the intended separation outcome) and retentate (residual result) (Judd, 2008). Because the separation is no longer subject to hydrodynamic conditions such as sludge retention time, hydraulic retention time, and sludge removal rate, the use of membranes produces a more flawless separation performance (Kim et al., 2008; Ladewig and Al-Shaeli, 2017). The process of filtering sludge in MBR technology uses a membrane, whereas, in the activated sludge process, the sludge separation is accomplished by utilizing gravity in the settling tank (Le-Clech et al., 2006).

MBR configuration

The configuration of this MBR process varies depending on the quality of the wastewater to be treated and the location of the membrane against the reactor (Mackenzie L. Davis P.E., DEE, 2010). To carry out proper denitrification of the concentration of nitrate and nitrogen in the effluent, a procedure like the MBR can be provided within an anoxic zone that is established after aerobic processing. An anaerobic zone can also be used in this MBR process to improve the efficiency of lowering phosphorus levels (Huang et al., 2020; Le-Clech et al., 2006; Silva et al., 2017).

These are the various MBR process configuration two types. First type is internal membrane (submerged membrane), it can implement the membrane filter in the main bioreactor or a different tank. Membranes can have an online backwash system that uses a pump to reduce fouling on the membrane surface. It can be flat, tubular sheets, or a combination of both. To prevent fouling, additional aeration is also required to generate water pressure. Second types is external membrane (side stream membrane), the membrane is installed outside the bioreactor after the position of the bioreactor. Biomass is injected directly into the membrane module installed in series, and the recirculation flow returns to the bioreactor to manage the MLSS concentration (Mixed Liquor Suspended Solids). Reactors with pumps and pipes can also be used to perform the membrane removal procedure. The submerged membrane system is the most common since the energy used is less and more stable. According to this study, the submerged membrane is the type of membrane technology utilized to treat grey water.

Performance mechanism for MBR

Aerobic and anaerobic biodegradation processes, the effectiveness of the wastewater treatment procedure in the biodegradation process is significantly influenced by microorganisms. In the waste plant, microorganisms break down organic substances to produce energy, which is then used for their growth. Membrane System, the membrane has a thickness of between 0.1 and 0.5 mm and is a thin, semi-permeable layer. The membrane functions as a filter and barrier for molecules that pass through it. After the flow has passed through the membrane system, very small particles can be trapped, making this device highly effective at preventing the passage of very small pollution particles. This ability is based on the size and energy of the flow. The membrane system's disadvantage is clogging. The longer it is worked, the more particles will build and potentially clog the flow path. Consequently, occasional backwashing is necessary. Figure 1 is a detail of the membrane bioreactor process,

RESULTS AND DISCUSSION

The installation and application system of MBR technology is carried out in the office area of the Ministry of Health, Surabaya. Utilizing Zenon MBR technology and a feed tank with a total volume of 1.5 m^3 to function as a sedimentation tank and to balance the incoming flow. The grey water generated by office activities is

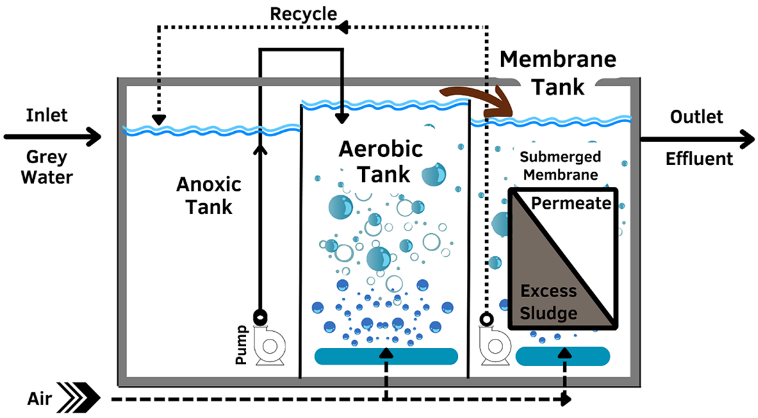

Figure 1. Schematic layout of the submerged membrane bioreactor

pumped from the sewer based on the feed tank's level control. The submerged ultrafiltration (UF) module used by this MBR has a cut-off size of 50 nm or less. Samples from the influent and effluent streams were taken for 70 days (one week) as part of an approved environmental laboratory test to track the operational effectiveness of the bioreactor. Parameters chemistry and microbiology each examined a variety of parameters, including BOD_5, COD, TSS, TOC, nitrate-nitrite, detergent, and total *coliform*. The results of using a membrane bioreactor in detail are presented in Table 1.

The results of Table 1 explain that the maximum efficiency rate of using a membrane bioreactor (100%) for the parameters of total *coliform* and *Escherichia coli*. The next parameter that has the highest efficiency rate for TSS reduction is 97%. On the other hand, the use of a membrane bioreactor cannot reduce the concentration of NO_3 and NO_4 parameters. To find out the MBR performance, an analysis of gray water is carried out every week to get trends from performance effectiveness to find out the magnitude of the decrease in the pollutant parameters. The results of the study can be seen in Figures 2, 3 and 4.

Almost all water quality indicators from all examined samples that were treated with MBR technology exceeded the standards, according to the analysis's results, including the concentrations of the microbiological parameters Total *coliform* and *Escherichia coli*. According to the examination of the treated water's quality, the concentration exceeds the government's guidelines for environmental quality. The results of applying MBR technology to reduce the concentration levels of processed office grey water averaged up to a reduction of 90%. Compared to industrial wastewater, grey water has a relatively high concentration of organic matter, severe physicochemical parameters (pH, temperature, and salinity), and natural compounds with risk factors and the potential to obstruct biological treatment processes (Bani-Melhem and Smith, 2012; Kadim and Abd, 2022; Luján-Facundo et al., 2019).

Table 1. Test results for chemical and biological parameters using a membrane bioreactor

Parameters	Concentration influent	Concentration effluent	Efficiency rate (%)
BOD_5 (mg/L)	139.12 ± 16.47	10.27 ± 1.20	93%
COD (mg/L)	354.85 ± 13.82	21.24 ± 2.41	94%
TOC (mg/L)	56.2 ± 2.22	7.48 ± 0.92	87%
TSS (mg/L)	85.35 ± 2.32	2.79 ± 0.59	97%
NH 3-N (mg/L)	18.07 ± 2.18	1.38 ± 0.49	92%
NO 3-N (mg/L)	0.51 ± 0.05	7.43 ± 1.11	-
NO 2-N (mg/L)	0.02 ± 0.003	0.2 ± 0.02	-
Detergents (mg/L)	6.2 ±0.98	0.39 ± 0.08	94%
Total *coliform* (< 1.8 MPN/100 mL)	1 x 106	0	100%
Escherichia coli (< 1.8 MPN/100 mL)	1 x 105	0	100%

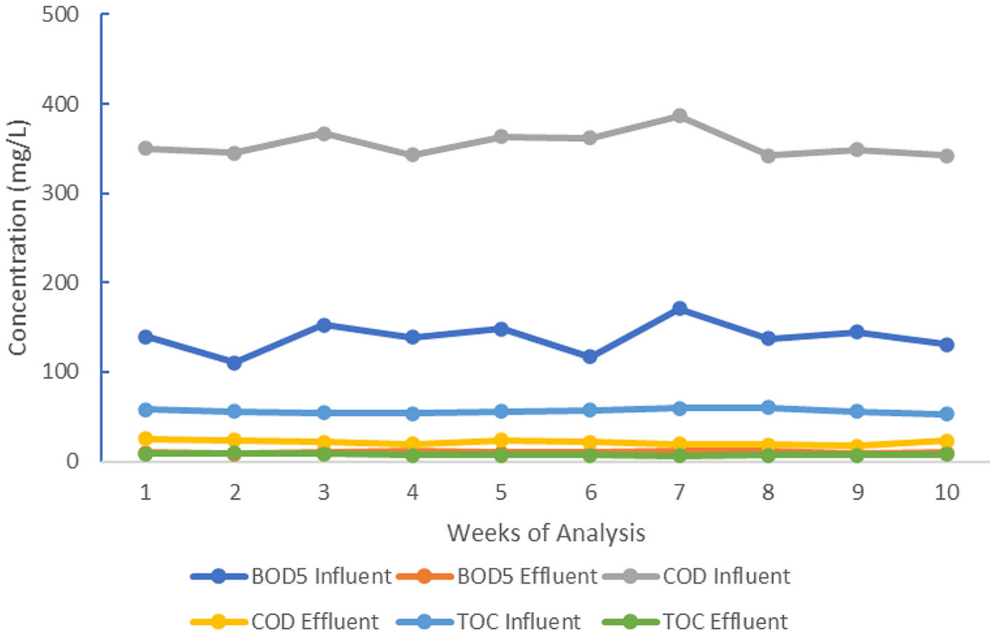

Figure 2. Basic parameter analysis results of greywater in membrane bioreactor

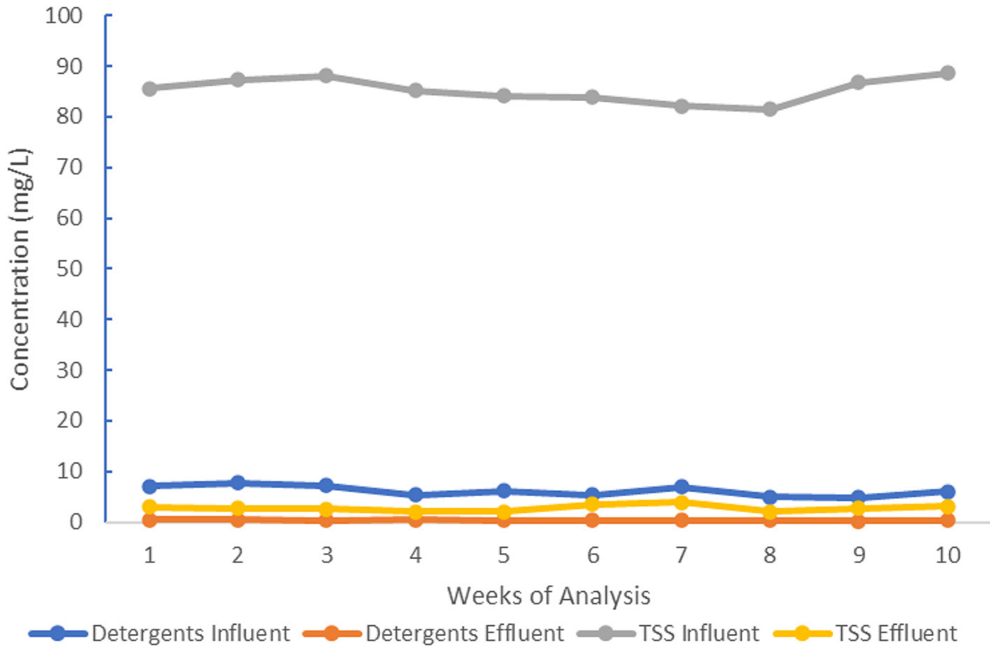

Figure 3. Reduction of detergent levels of greywater in membrane bioreactor

Both nitrification and denitrification are ongoing processes. The nitrification process that converts NH_3 into NO_{3-}, is carried out under aerobic conditions, while denitrification which reduces nitrates to atmospheric nitrogen occurs only in anaerobic conditions (Afifah et al., 2021). Because the MBR technology system's primary purpose is to clean the UF membrane and prevent fouling, it is not possible to reduce the level of aeration. This is designed to prevent backwashing or chemical cleaning of the membrane (Ding et al., 2016; Fountoulakis et al., 2016; Hocaoglu et al., 2013). However, the levels of nitrate and nitrite in grey water treated using MBR still meet environmental quality criteria. Meanwhile, the efficiency rate for the principal pollutant elimination from wastewater is 90%. This MBR technology has proven to be effective as a grey water recycling module that may be used as a backup for clean water needs in the future.

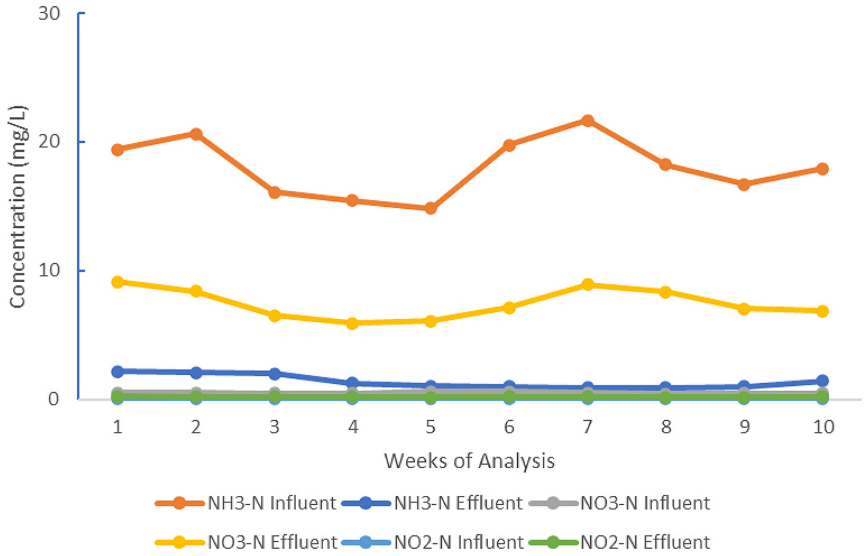

Figure 4. Measurement results for ammonia parameters and nitrification process of greywater in membrane bioreactor

CONCLUSIONS

The use of membrane bioreactor (MBR) technology for greywater treatment is an effective alternative technology. Bioreactor membrane technology is proven to reduce wastewater pollutants BOD_5 (93%), COD (94%), TOC (87%), NH_3 (92%), detergents (94%), total *coliform* and *Escherichia coli* (100%) so that it can be applied as a domestic wastewater treatment technology. However, membrane bioreactor technology cannot be used to remove NO_3 and NO_4 pollutants. Future studies can develop anaerobic tanks in membrane bioreactor technology or other alternative technologies in removing NO_3 and NO_4 with the use of algae and a combination of effective microorganisms.

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